3.1 Introduction

On one hand the development of materials to improve the sensitivity, selectivity, response time etc., is the need of the time and on the other hand suitable setups to detect gas and study the gas sensing properties has become an essential requirement.

In the present day various analytical instruments are employed for gas detection and they provide fairly accurate information about the gaseous species. These setups are used to analyses air pollutants and detect explosives at airports, drug abuse screening etc. These instruments require skilled knowledgeable operators [1]. They are expensive, suitable for laboratory table tops, bulky in size and are used as a last resort for applications where no suitable gas-sensing device is readily available. T. Machappa et al., have reported a setup for LPG sensing [2] Many researchers have proposed different type of sensor units [3-6] There is a strong need to develop and fabricate miniaturized, cost effective and user friendly setups for gas sensing.

In the present work, we have developed and fabricated two gas sensor setups. One is a miniaturized and a low cost setup that works at an operating temperature of about $150^0$ C. And the other one is a laboratory table top setup, which is cost effective, simple and easy to operate. This setup operates from room temperature to $450^0$ C.
3.2 Design and Fabrication of Miniaturized Gas Sensor

Photograph of our miniaturized gas sensor setup is shown in figure 3.1

![Photograph of Our Miniaturized Gas Sensor Setup](image)

Fig. 3.1: Photograph of Our Miniaturized Gas Sensor Setup

The schematic diagram of the experimental setup of this miniaturized gas sensing unit is shown in Figure 3.2. A printed circuit board (PCB) strip (a) of width 1 cm and length 7 cm is used as platform to design the present setup. Four copper contacts (b) along the length are made on PCB by etching out unwanted copper using ferric chloride solution. Out of these contacts; two are used for electrical resistance measurements and the other two for power to micro heater. An
electrical heater is prepared using resistors that are commercially available at any electronic shop; the micro heater has dimensions 10 mm x 7 mm x 2 mm with resistance 101 Ω. A D.C. voltage of 12.5 V is applied to the heater that gives temperature of the oven about 110˚C within three minutes. A small oven (c) having dimensions 10 mm x 10 mm x 8 mm with a micro heater (d) embedded in it is made as shown in figure (3.2). The inner volume of 10 mm x 6 mm x 5 mm is available for the mounting of sensor element. The oven is fixed at one end of the PCB and the other end is passed through the cork of the bottle such that the PCB is projected about 1 cm outside the bottle surface. The sensor element (e) of SnO₂ thin film is loaded in the oven and the contacts are soldered to the copper electrodes meant for fixing the sample on the
PCB. This entire assembly is housed in a 15 ml laboratory cultured bottle; figure (3.3) shows the photograph of the complete setup.

![Photograph Showing the Details of Fabrication of Miniaturised Gas Sensor Setup](image)

**Fig. 3.3: Photograph Showing the Details of Fabrication of Miniaturised Gas Sensor Setup**

The above sensing element (shown in fig 3.3) with electrical contacts is placed in a small oven designed for localized heating. The gas response in terms of the variation in resistance when exposed to gas at different temperatures is recorded. H₂S gas is used to test the performance of the gas sensor unit. Every time a known amount of H₂S gas is injected into the bottle and sealed tightly and the variation in the resistance of the thin film is recorded as a function of time. It is found that there is decrease in resistance of the sensing element in presence of H₂S gas. When the H₂S gas is injected into the unit, the resistance of the element decreases rapidly and reaches a constant value in a short course of time. When the element is exposed to air by opening the cap and keeping bottle quite away the resistance of the element increases.
and reaches its initial value. The decrease in resistance with respect to time is recorded when exposed to \( \text{H}_2\text{S} \) gas and the increase in resistance with respect to time is recorded when exposed to open air. This procedure is repeated for several times and obtained reproducibility curves are discussed further in next chapter.

### 3.2.1 Gas Sensing Element for Setup

In order to use \( \text{SnO}_2 \) for gas sensing application, the as prepared \( \text{SnO}_2 \) films were cut into small pieces having width 5 mm and length 7 mm. These films were washed with de-ionized water and rinsed in boiling trichloroethylene (\( \text{C}_2\text{HCl}_3 \)) solution to degrease them. Later on either side of the film surface along the length two thin copper wires are attached by applying silver paste and allowed to dry for an hour under table lamp and then an adhesive araldite is applied at the edges and kept for about 10-12 hours in order to have physically firm contacts. The schematic diagram of the as prepared sensing element is shown in Fig. 3.4:

**Fig. 3.4: Schematic diagram of sensor element**

are attached by applying silver paste and allowed to dry for an hour under table lamp and then an adhesive araldite is applied at the edges and kept for about 10-12 hours in order to have physically firm contacts. The schematic diagram of the as prepared sensing element is
shown in figure (3.4). The area available between the two copper wires is an active region for gas sensing measurements.

### 3.3 Laboratory Setup for Gas Sensing Measurements

The photograph of the designed Laboratory gas sensor setup is shown in Figure (3.5 & 3.6) and its schematic diagram in fig (3.7).
A circular Aluminum disc of diameter 32 mm and thickness 11mm (a) with a pencil heater (b) of 12W embedded in it is used as a heating element for localized heating of the film. One junction of

Fig.3.6: Photograph showing the Details of Fabrication of Our Laboratory Gas Sensor Setup
Thermocouple (c) using Alumol Chromel is fixed in contact with the heating element for temperature measurements. Below this a Teflon spacer (d) of diameter 32 mm and thickness 9 mm is provided for thermal insulation. Above the heating element, SnO$_2$ thin film sample of size 2mm x 6mm is mounted as gas sensing element (e). Two spring loaded connectors (f) are provided for electrical connection for the resistance measurements.

This assembly is housed in a glass cylinder of diameter 110 mm and length 115 mm (g) with one an annular aluminum disc attached on

![Fig. 3.7: Schematic of Our Laboratory setup for gas sensing](image)
either side of the glass cylinder. A flange coupling using O ring (h) with circular Aluminum discs either side (one top and one bottom) is use for air tight compartment. All electrical connections are drawn through the bottom plate. In the top plate (lid) a septum (i) is provided to inject the gas into the chamber using a syringe.

A cork (j) is used to let the dry air into the chamber and expose the films to air. This entire assembly is mounted on a wooden base fixed with a panel of six connector sockets (k); two for resistance measurements, two for applying voltage to the heater and two for temperature measurements. A syringe (l) is used to inject the gas into

Fig. 3.8: Photograph of Laboratory Setup with Power Supply and Meters connected for Gas Sensing
the chamber. A d.c power supply 0-30V and 5 A is used for applying voltage to the heater; a temperature indicator is used for temperature measurements. And a digital multimeter is used for resistance measurements. Complete experimental arrangement using setup is shown in figure 3.8

The gas response in terms of the variation in resistance when exposed to gas at different temperatures is recorded. H$_2$S gas is used to test the performance of the gas sensor unit. Every time a known amount of H$_2$S gas is injected into the chamber and the variation in the resistance of the thin film is recorded as a function of time. It is found that there is decrease in resistance of the sensing element in presence of H$_2$S gas. When the H$_2$S gas is injected into the unit, the resistance of the element decreases rapidly and reaches a constant value in a short course of time. When the element is exposed to air by opening the cork and allowing the air to enter the chamber, the resistance of the element increases and reaches its initial value. The decrease in resistance with respect to time is recorded when exposed to H$_2$S gas and the increase in resistance with respect to time is recorded when exposed to open air. This procedure is repeated for several time and obtained reproducibility curves (discussed in next chapters)
3.4 Conclusions

The two gas sensor setups quite simple, cost effective, reliable and sensitive to detect various gases. The workability of these setups is clearly shown in the gas response characteristic curve that is electrical resistance verses time. (Chapter-4)

Our miniaturized gas sensor setup is simple, cost effective and portable. This setup has been proposed to measure the gas response of different gases in terms of the variation in resistance of the sensing element. It can operate between a temperatures ranging from room temperature to 150°C. The workability of this setup has been tested using SnO$_2$, SnO$_2$-TX100, SnO$_2$-PEG600 thin films for H$_2$S gas. It can be extended to other sensing materials and also for other gases of interest. This part of the work has been published in the IOSR journal of Physics [7]

Our laboratory setup for gas sensing is simple, table top, cost effective and simple. Conveniently the sensor element (thin film) can be loaded using spring loaded contacts. This setup has been proposed to measure the gas response of different gases in terms of the variation in resistance of the sensing element. It can operate between a temperatures ranging from room temperature to 400°C. The workability of this setup has been tested using SnO$_2$, SnO$_2$-TX100, SnO$_2$-PEG600 thin films for H$_2$S gas. It can be extended to other sensing materials and also for other gases of interest. This part of the work has been published in the IOSR journal of Physics [8]
3.5 References


